

# **Reduce the Failure Rate of the Screwing Process with Six Sigma Approach**

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## **Abstract**

The Six Sigma approach is a well-structured method for improving quality level by detecting and reducing the variability of the process. Six Sigma approach also helps to achieve the company's strategic goals by managing the several Six-Sigma projects. There are five sequential phases that are Define, Measurement, Analysis, Improvement and Control of the Six Sigma Project. These phases lead the way to carry out to the project. At the end, defective units will be decreased and/or the process capability index is increased. In this study, the screwing process is examined as a Six Sigma project. The aim of this project is to reduce the failure rate of screwing process in the white appliance factor in Turkey. Mentioned five phases are applied. The experimental design and analysis are handled. Finally, the pin shape and the type of handgun are determined as effective factors. Also, the best levels of these factors are found. The failure rate of screwing process is decreased from 30% to 14%. This study proposes the Six-Sigma projects with all phases sequencing and presents the results are originated the deviations from the manufacturing process.

## **Keywords**

Six sigma, screwing process, quality improvement

## **1. Introduction**

The Six Sigma approach was firstly introduced by Motorola. Then, Six Sigma has been successfully through many organizations such as GE, Texas Instruments, Sony, Nokia, LG and ABB with the aim of reducing quality costs. Six Sigma is a well-structured and quantitative approach to improve product and process quality using statistical techniques by reducing the variability of process/ product.

It has five steps DMAIC (Define, Measurement, Analyze, Improve, and Control). Define step include the definition of the problem with quantitative scale like defect per unit or process capability index. Also, all quality characteristics on the process/ product are determined with SIPOC diagram (Supplier, Inputs, Process, Outputs, Customers) or process map. In Measurement step, data from quality characteristics and analysis are collected. Gage R&R studies carried out on the quality characteristics. Also the critical-to-quality characteristics (CTQs) of the process or product identified with the cause and effect diagram. In Analysis step, data from CTQs are analyzed several statistical tools such as test of hypothesis, box-plot, ANOVA etc. The analyzing of CTQs is the baseline for understanding the root cause of why defects occurred. In Improvement step, design and analysis of experiments are conducted on the CTQs to determine effective factors and their levels on the problem. Also, the modified defect per unit or process capability index is calculated for exhibiting of the improvement. The last step is Control. In this step, the determined process/ product factor levels are applied and standardized with procedures or instructions.

There are several studies on literature about the application on Six Sigma. Apak and et al. applied the Six Sigma methodology on the hydrogen energy to boost energy efficiency and to emphasize the importance of exploring potential future sources of sustainable, reliable and competitively priced energy (Apak et al. (2012).

Kim et al. used the Six Sigma phases to the chemical process industry to improve the process capability They improved process from 3.5 sigma level to the 5.5 sigma level (Kim et al. 2003).

Koziołek and Derlukiewicz presented the methodology for assessing the process of designing and constructing vehicles and machines, which implements Design for Six Sigma tools. They also showed the requirements needed to implement the method and the benefits arising from the use of quality assessment tool (Koziołek and Derlukiewicz 2012)

Sahoo et al. focused on implementing the DMAIC based Six Sigma approach in order to optimize the radial forging operation variables. They minimize the residual stress developed in components manufactured by the radial forging process. To optimize the results obtained and to make the analysis more precise and cost effective, response surface methodology (RSM) was also incorporated (Sahoo et al. 2008)

Shirazi et al. illustrated a paper for reducing variability of material flow and establishing balanced zone layout, some new constraints have been added to the problem based on six sigma approach. They constructed a non-linear multi-objective problem for minimizing the material flow intra and inter-loops and minimization of maximum amount of inter cell flow, considering the limitation of TAGV work-loading (Shirazi et al. 2010).

Kumar et al. presented a paper that includes two optimization models that will assist management to choose process improvement opportunities are presented. The first model is to maximizing the sigma quality level of a process under cost constraint, and the second model select of Six Sigma alternatives to maximize process returns (Kumar et al. 2008)

Also some papers consider Six Sigma as general concepts like Six Sigma educations (Kwaka and Anbar 2006), (Fouweather et al 2006) and (Mehrabi 2012) selection of Six Sigma projects (Büyükozkcan and Öztürkcan 2012) , (Saghaei and Didekhani 2011), ( Bilgen and Sen 2012) and (Padhy and Sahu 2011).

In this study, the screwing process on the the rare base points on the product is analyzed in white appliance factory in Turkey. There are many holes on the product and the rare base points are assembled with the help of equipment to these holes. It may be occurred some shifts and defects while assembling the rare base points. Mentioned five step of Six Sigma approach are applied.

## **2. Six Sigma Steps for Screwing Process and Results**

The six sigma approach is aimed to reduce the variation on the effective factors in the process after the effective factors for the problem are determined. The six-sigma approach is also a project-driven management tool for improving the productivity, financial performance and customer satisfaction. Many applications of the six sigma approach in many organizations are provided sustainable development of their quality by integration their process knowledge with the statistical tools.

### **2.1. Define Phase:**

This study proposes the six sigma study carried out to improve the screwing process of the rare base points of a white appliance product in the factory located in Turkey. Firstly, problem is defined, the SIPOC diagram is constructed, the cause and effect diagram is set for the screwing process problem and process map is drawn in Define Phase. The SIPOC diagram is shown in Figure 1. Also, the cause and effect diagram is given in Figure 2.



## 2.2. Measure Phase:

Secondly, the failure rate of screwing process is figured out in the present situation. The panel and the measurements of holes on the panel is presented in Figure 3. The Gage R&R study is performed for the measures of the hole locations on the back consolidation that carry the compressor in Measurement Phase. The Gage R&R values of all measurements are acceptable (Gage R&R% < 30%).



Figure 3: The panel and the measurements of holes on the panel

## 2.3. Analysis Phase:

Thirdly, data about the failure rates are collected and analyzed with tests of hypotheses on two proportions based on lot by lot among assembling lines, and among several holes on the back consolidation. The hypothesis on the lot for a1 and b1 measurement is given in Eq.1. The result of analysis shows that there is no any statistical differences between lots for a1 and b1 measurements because of the p-values' > 0.05 where 5% values represents the confidence level, given is Table 1 and Table 2, respectively. It is conclude that the hole measurements doesn't change lot by lot.

### Hypothesis

$$\begin{aligned}
 H_0: \mu_1 &= \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 \\
 H_a: \mu_i &\neq \mu_j \text{ for at least one } (i \neq j)
 \end{aligned}
 \tag{1}$$

Table 1: One factor analysis on a1 measurement

One-way ANOVA: a1 versus lot					
Analysis of Variance for a1					
Source	DF	SS	MS	F	P
lot	5	0.0408	0.0082	0.25	0.933
Error	24	0.7681	0.0320		
Total	29	0.8089			
Individual 95% CIs For Mean Based on Pooled StDev					
Level	N	Mean	StDev	-----+-----+-----+-----+-----	
1	5	5.2980	0.1013	(-----*-----)	
2	5	5.3860	0.2288	(-----*-----)	
3	5	5.3760	0.1873	(-----*-----)	
4	5	5.3200	0.1162	(-----*-----)	
5	5	5.3820	0.1927	(-----*-----)	
6	5	5.3960	0.2091	(-----*-----)	
-----+-----+-----+-----+-----					
Pooled StDev =		0.1789		5.16	5.28 5.40 5.52

Table 2: One factor analysis on b1 measurement

One-way ANOVA: b1 versus lot					
Analysis of Variance for b1					
Source	DF	SS	MS	F	P
lot	5	0.1382	0.0276	1.17	0.352
Error	24	0.5664	0.0236		
Total	29	0.7047			
Individual 95% CIs For Mean Based on Pooled StDev					
Level	N	Mean	StDev	-----+-----+-----+-----	
1	5	22.680	0.081	(-----*-----)	
2	5	22.680	0.228	(-----*-----)	
3	5	22.742	0.171	(-----*-----)	
4	5	22.744	0.102	(-----*-----)	
5	5	22.664	0.197	(-----*-----)	
6	5	22.864	0.067	(-----*-----)	
-----+-----+-----+-----					
Pooled StDev =		0.154		22.65	22.80 22.95

Then, the failure rates are examined before and after waiting in which the shrinkage occurs during waiting time. The hypothesis is conducted on the before waiting failure rate (p1) and after waiting failure rate (p2). This tests imply that the waiting time is an effective factor (p-value < 0.05) for screwing problem because of the shrinkage of the refrigerator panels.

Hypothesis

$$H_0: p_1 = p_2$$

$$H_a: p_1 \neq p_2$$

Table 3: Two proportion test on the before and after waiting failure rates

Test and CI for Two Proportions			
Sample	X	N	Sample p
Before waiting	10	261	0.038314
After waiting	94	507	0.185404
Estimate for p(1) - p(2): -0.147090			
95% CI for p(1) - p(2): (-0.188159; -0.106021)			
Test for p(1) - p(2) = 0 (vs not = 0): Z = -7.02 P-Value = 0.000			

The mechanical component like handgun for screwing process is required to repair. Also, the failure rates of both before and after repairing are statistically tested whether it is significant or not in the Analysis Phase. There are significant differences on failure rates (p-value < 0.05) according to the Table 4.

Table 4: Two proportion test on the failure rates of both before and after repairing of handgun

<b>Test and CI for Two Proportions</b>			
Sample	X	N	Sample p
Before repairing	99	1041	0.095101
After repairing	11	522	0.021073
Estimate for p(1) - p(2): 0.0740281			
95% CI for p(1) - p(2): (0.0523631; 0.0956931)			
Test for p(1) - p(2) = 0 (vs not = 0): Z = 6.70 P-Value = 0.000			

Two handguns, pneumatic and electric; for screwing are used in the process. It is analyzed to determine the differences between two types of handgun in statistically. It is shown that the failure rate of pneumatic handgun is significantly less than the failure rate of electric handgun, like in Table 5.

Table 5: Two proportion test on the pneumatic and electric handgun failure rate

<b>Test and CI for Two Proportions</b>			
Sample	X	N	Sample p
Pneumatic	72	3248	0.022167
Electric	121	2494	0.048516
Estimate for p(1) - p(2): -0.0263490			
95% CI for p(1) - p(2): (-0.0361846; -0.0165133)			
Test for p(1) - p(2) = 0 (vs not = 0): Z = -5.25 P-Value = 0.000			

#### 2.4. Improve Phase:

The type of handgun for screwing process is selected. The effect of waiting of the product is determined and taken some precautions. The experiment is conducted on the pin shape and type of the handgun with two levels that: triangular pin shape and trapezoidal pin shape; pneumatic handgun and electric handgun in Table 6. Trapezoidal pin shape and electric handgun are used in present for screwing. After the results of experiments are analyzed with ANOVA in Table 7, it is conclude that the triangular pin shape and the pneumatic handgun should be preferred for the minimum failure rate according to the Figure 4. The used trapezoidal pin shape and proposed triangular pin shape are given in Figure 5.

Table 6: Factors and levels in experiments

Factors	Levels	
Pin shape	Triangular	Trepozidial
Type of handgun	Pneumatic	Electric

Table 7: The ANOVA Table of the experiments

Fractional Factorial Fit: failure rate versus pin shape; type of handgun						
Estimated Effects and Coefficients for failure (coded units)						
Term	Effect	Coef	SE Coef	T	P	
Constant		0.07524	0.002056	36.60	0.000	
pin shap	0.08212	0.04106	0.002056	19.97	0.000	
type of hang	0.04627	0.02314	0.002056	11.26	0.000	
pin shap*type of	0.02143	0.01071	0.002056	5.21	0.006	
Analysis of Variance for failure (coded units)						
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	2	0.0177718	0.0177718	0.00888589	262.83	0.000
2-Way Interactions	1	0.0009181	0.0009181	0.00091806	27.15	0.006
Residual Error	4	0.0001352	0.0001352	0.00003381		
Pure Error	4	0.0001352	0.0001352	0.00003381		
Total	7	0.0188251				

Figure 4: The interaction plot of pin shape and type of handgun

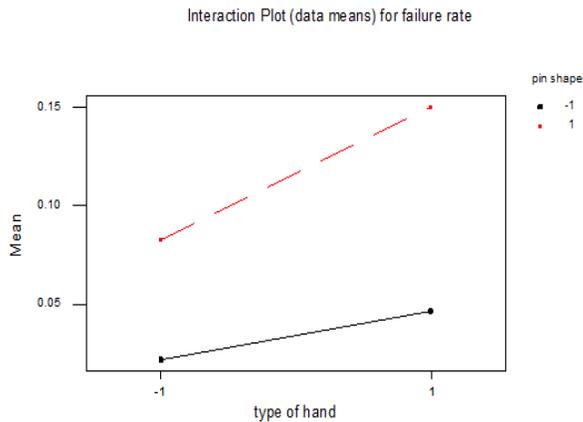
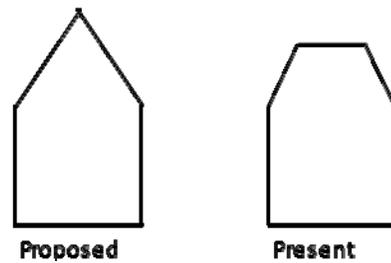


Figure 5: Pin shapes



### 2.5. Control Phase:

Finally, the failure rates are monitoring with fraction nonconforming control chart after applying the triangular pin shape and pneumatic handgun for screwing process. It is decided that these determining best levels of effective factors will be applied to the other assembling lines.

### 3. Conclusions

The six sigma approach is carried out to decrease the failure rate for the screwing process of the back consolidation to the side panels of product. It is concluded that the type of handgun and the shape of pin are effective factors on the failure rate of the screwing process. Therefore, the statistical background and the process knowledge are combined to reduce the failure rate in these six sigma study. Also the failure rate are decreased from 30% to 14% with this Six Sigma project. This study presents the Six-Sigma project with all steps to reduce the deviations in the manufacturing process and contribute the decline of the failure rate in the assembling process.

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### Biography

**Erginel Nihal** is an Associated Professor and vice chair of Anadolu University, Industrial Engineering Department, Eskisehir TURKEY. She earned B.S. at 1988 and M.S. at 1991 in Industrial Engineering at the Anadolu University, Eskisehir, TURKEY. She took PhD at 1999 from Osmangazi University in Turkey. She worked Arcelik Refrigerator Factory that is an appliance firm between 1995 and 2001. She is a Black Belt and expert on ISO9001. She is also a trainer in the Turkey Society of Quality. Her courses and main areas are probability, statistics, quality control, total quality management, six sigma and ISO9000's.

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